Cur
[Cur HS 18A]
April 1940

APRIL, 1940
3,000—R456

OHEC
373 1909713
059DE/C-Ch

ONTARIO
Department of Education

Courses of Study

Grade XIII

CHEMISTRY and PHYSICS

Issued by Authority of
The Minister of Education

Ministry of Education, Ontario
Historical Collection

CHEMISTRY, GRADE XIII

This course in Chemistry is a continuation of that prescribed in Grades XI and XII (Chemistry or Agriculture, Part II). It is outlined in detail in order to give the teacher a definite guide as to what topics should be studied. The number of periods given is merely a suggestion or guide as to "depth" of treatment. Some topics might require more time while others could be shortened.

The sequence of topics as presented is suggested as a logical arrangement, but may be varied at the discretion of the teacher. The periodic classification of elements, for instance, may be taught whenever the teacher considers it most satisfactory. Fundamental principles and experimental work should be emphasized. Pupils should be encouraged to use books of reference.

Review.
(Nine periods.)

Recall the states of matter.

An experimental review of the characteristics of pure substances, mechanical mixtures and solutions.

An experimental review of the physical and chemical properties of (a) oxygen, (b) hydrogen, (c) carbon, (d) nitrogen, (e) sulphur. (The compounds of these elements are not to be studied at this stage.)

Principles of the Periodic System.
(Nine periods.)

A brief reference to the early historical development of Mendelejeff's Periodic Table.

An experimental study of (a) sodium and potassium, (b) chlorine, bromine and iodine, to show their organization into families. The relationship within the sodium family may be shown by studying (i) the action of the metals with oxygen, chlorine and water; (ii) a comparison of the hydroxides, carbonates and chlorides. Within the chlorine family it may be shown by (i) the similarity in methods of preparation of the elements; (ii) the action of chlorine, bromine and iodine upon aqueous solutions of potassium chloride, potassium bromide and potassium iodide; (iii) the action of phosphorus and copper on chlorine, bromine and iodine vapour; (iv) the action of concentrated sulphuric acid on potassium chloride, potassium bromide and potassium iodide.

A discussion of the relationship in properties of the elements and their compounds as shown by the preceding experiments to illustrate the orderly arrangement of the elements in the periodic classification.

Atoms and Molecules.
(Four periods.)

Recall the Law of Reacting Weights and Gay-Lussac's Law of Volumes; a brief discussion of the molecular and atomic theories in relation to these laws.

Review the "Conductivity of a Gas" (Physics, Grade XII) to show that an atom is not indivisible. In gases conducting electric current an atom breaks into positively and negatively charged particles. The electron is common to all atoms and has negligible mass. The positively charged part (the nucleus) carries almost the whole mass. A concept of the structures of the hydrogen and chlorine atoms with respect to the nucleus and electrons (a plane projection of the Bohr concept is suggested).

Extension of the above to show (i) the law of octaves in relation to the theory of stable octets, and (ii) that related elements in the Periodic Table have similar arrangements of outer electrons and that the valence relations depend on the giving and taking of electrons to form stable electron shells.

Heavy water and the isotopes of hydrogen; isotopes of chlorine. Isotopes differ only in atomic weight (mass of the nucleus) and scarcely at all in properties (electron structure).

Canadian production of uranium and radium. Characteristics of radio-active disintegration. Uses of radium.

NOTE:—It should be stressed that ideas of the arrangement of nucleus and electrons are constantly changing.

Factors Affecting Rate of Reactions.
(Four periods.)

A study of the effect of (1) heat, (2) light, (3) concentration, (4) catalysis, (5) surface area, on the rate of reaction.

The following experiments are suggested:

(1) Heat; the gradual heating of crystals of ammonium dichromate.
(2) Light; the effect of light on freshly precipitated silver chloride.
(3) Concentration; recall the burning of substances in air and in oxygen.
(4) Catalysis; recall the action of manganese dioxide on heated potassium chlorate.
(5) Surface Area; the addition of acid to equal weights of crystalline and of powdered washing soda.
(6) The effect of various factors combined as shown by the action of oxalic acid and sulphuric acid on a solution of potassium permanganate.

Equilibrium.
(Seven periods.)

Recall the vaporization of bromine in a stoppered bottle partly filled with liquid bromine (Change of State, Grade XI).

Equilibrium as illustrated by the vapour pressure of benzene and of water as determined by introducing a few drops of (1) benzene, (2) water, into the vacuum of a mercury barometer. The effect of changing the temperature in displacing the equilibrium should be shown (the barometer tube may be fitted into a Liebig condenser jacket and the temperature changed by hot or cold water).

Reversible reactions and conditions that affect equilibrium, as illustrated by (a) water $\rightleftarrows$ water vapour, (b) ice $\rightleftarrows$ water, (c) ice $\rightleftarrows$ water vapour, (d) sugar (solid) $\rightleftarrows$ saturated solution of sugar, (e) hydrated copper sulphate $\rightleftarrows$ anhydrous copper sulphate and water, (f) calcium carbonate $\rightleftarrows$ calcium oxide and carbon dioxide, (g) solutions of ferric chloride and ammonium thiocyanate $\rightleftarrows$ ferric thiocyanate and ammonium chloride.

The Theory of Ionization of Acids, Bases and Salts.
(Eight periods.)

A demonstration of the electrolysis of cupric chloride with an explanation in terms of charged particles.

Recall the structure of the hydrogen atom (one valence electron) and the chlorine atom (seven valence electrons).

A discussion of the formation of the hydrogen chloride molecule by the lending of the hydrogen electron to the chlorine atom to complete the stable octet.

The tendency of the hydrogen atom to lend an electron to form the hydrogen ion.

A discussion of the dissociation of hydrogen chloride when dissolved in water as giving rise to electrically charged particles or ions.

A discussion of the hydrogen ion as being the characteristic ion of acids, and of the properties of acids (taste, effect on litmus and other indicators, action on metals, etc.) as being due to hydrogen ions in the solution.

A discussion of the ionization and electrolysis of common salt solution and the importance of the products. Faraday's Law and electrochemical equivalents (recall chemical effects of electric current of Grade XII Physics). Explanation of these laws in terms of charges on ions—univalent negative ion bearing one extra electron, etc.

Experimental study of the equilibria: (a) cupric bromide molecules $\rightleftarrows$ cupric ions and bromine ions (as shown by change of colour on dilution), (b) barium chloride molecules $\rightleftarrows$ barium ions and chlorine ions (as shown by the addition of concentrated hydrochloric acid to a saturated solution of barium chloride).

A brief discussion of the measurement of degree of acidity in terms of hydrogen-ion concentration, and of degree of basicity in terms of hydroxyl-ion concentration.

The meaning of the terms "concentration" and "strength" (hydrogen-ion or hydroxyl-ion concentration) as applied to acids and bases.

Neutralization.
(Five periods.)

Experiments to show the neutralization reaction between acids and bases: the products of the reaction—water, and a salt which is left as a residue on evaporation of the water.

A discussion of neutralization as being a quantitative reaction depending on the removal of the hydrogen-ions and hydroxyl-ions to form water.

Experiments to show the volumes of sulphuric acid, nitric acid and hydrochloric acid, respectively, which will be necessary to neutralize any known weight of sodium hydroxide or potassium hydroxide dissolved in any quantity of water. NOTE:—The information (specific gravity, percentage by weight) given on the labels of acid bottles shows the relation between weight and volume.

A study of the ionic equations for several cases of neutralization; the negative ion of the acid and the positive ion of the base are unchanged.

Normal Solutions.
(Four periods.)

Calculation of equivalent weights of sulphuric acid and of sodium hydroxide.

Preparation of N/1 solutions (normal solutions) of sulphuric acid and sodium hydroxide.

Experiment to show the proportion by volume in which the above N/1 solutions react to completion.

The Hydrolysis of Salts.
(Two periods.)

An experimental study of the reaction on litmus and phenolphthalein of aqueous solutions of (1) salts of a strong base and a weak acid, such as potassium carbonate, borax; (2) salts of a weak base and a strong acid, such as copper sulphate, aluminium chloride; (3) salts of a weak acid and a weak base, such as copper acetate; (4) salts of a strong acid and a strong base, such as sodium chloride.

Molecular Weights.
(Three periods.)

A review of Reacting Weights (Grade XII).

Molecular Weights. An elaboration of the work covered in Grade XII.

Gay-Lussac's Law of Combining Volumes.

Avogadro's Hypothesis.

Simple Problems.
(Seven periods.)

(a) To find (1) the reacting weight of an element from the composition of its oxide, (2) the simplest formula from the percentage composition, (3) the percentage composition of a compound from its formula.

(b) To determine molecular formulae.

(c) To calculate from equations representing reactions the proportion by weight and by volume of the pure substances involved in these reactions. (These problems need not involve concentration or density of reagents, or aqueous vapour pressure).

Elements and Compounds.

A discussion of the industrial importance of the common metals and non-metals of the following groups and their compounds. The relationship between uses and properties should be stressed.

Note 1:—Teachers may find it more convenient to study certain compounds with groups other than those with which they are listed; e.g., calcium cyanamide may be studied with either the calcium compounds or the nitrogen compounds.

Note 2:—The elements and compounds marked with an asterisk (*) are to be studied in detail; also one modern method of commercial preparation of each. The pupils need not reproduce the diagrams of plant or apparatus. The other elements and compounds mentioned are to be considered only in regard to formula, appearance and important uses, and as far as possible to show the relation between properties and uses.

Group I.
(Seven periods.)

Sodium, potassium, *sodium chloride, *sodium hydroxide, *sodium carbonate, *sodium bicarbonate (Solvay process), sodium nitrate, sodium sulphate, potassium hydroxide, *potassium nitrate, potassium permanganate, potassium chlorate, copper, bluestone, copper oxide, silver, *silver nitrate, silver bromide, gold.

Group II.
(Six periods.)

Calcium, magnesium, zinc, mercury, calcium carbonate, *calcium oxide, calcium hydroxide, calcium bicarbonate, calcium chloride, calcium carbide, *calcium cyanamide, gypsum, plaster of Paris, magnesium carbonate, magnesium oxide, magnesium hydroxide, Epsom salts, magnesium chloride, zinc oxide, zinc sulphide, zinc hydroxide (as an amphoteric hydroxide forming zincates), zinc sulphide.

Group III.
(Three periods.)

Aluminium.

Aluminium oxide, aluminium hydroxide (amphoteric), aluminium sulphate (foam-type extinguishers), potassium alum.

Group IV.
(Five periods.)

Carbon, silicon, tin, lead.

A discussion of the relative acid-forming properties of carbon dioxide, silicon dioxide, tin dioxide, lead dioxide.

Contrast the characteristics of Group IV with those of Groups I and VII.

Review carbon and its compounds (Grade XI), silicon dioxide, *silicon carbide, silicates (reference to feldspar, mica, granite, glass), lead oxide, lead dioxide, red lead, lead carbonate, *white lead, lead acetate.

Group V.
(Eight periods.)

Nitrogen, phosphorus, arsenic, antimony, bismuth, *ammonia (synthetic process—Haber), ammonium hydroxide, ammonium salts, *nitric acid (oxidizing properties), common nitrates, nitrous oxide, *nitric oxide, *nitrogen dioxide.

Review nitrogen cycle.

Allotropic forms of phosphorus, phosphorus pentoxide, phosphoric acid, phosphorus sesquisulphide, arsenious oxide, lead arsenate.

Review periodic classification with special reference to phosphorus family.

Group VI.
(Six periods.)

Sulphur, oxygen, chromium.

*Sulphur dioxide, sulphurous acid, *sulphur trioxide, *sulphuric acid, carbon disulphide, *hydrogen sulphide, mineral sulphides of copper, lead, zinc, nickel, iron and silver.

Chromium, lead chromate, potassium dichromate, oxygen, ozone, hydrogen peroxide, sodium peroxide.

Group VII.
(Five periods.)

Fluorine, *hydrogen fluoride, sodium fluoride, calcium fluoride, *chlorine, *hydrogen chloride, calcium hypochlorite, bleaching powder, bromine, hydrogen bromide, iodine, hydrogen iodide, manganese dioxide.

Group VIII.
(Four periods.)

Iron, ferrous sulphate, oxides of iron, iron pyrites, nickel, platinum.

Tests for
Common Ions.
(Five periods.)

Solubility rules for solutions of the following salts should be memorized: nitrates, chlorides, carbonates, sulphates, and all salts of sodium, potassium and ammonium.

The detection of the following ions in solution: lead, silver, copper, ferrous, ferric, aluminium, zinc, ammonium, nitrate, sulphate, chloride, bromide, iodide, carbonate.

The flame tests for sodium, potassium, calcium.

NOTE.—Explanations of complicated tests for such ions as ferrous, ferric, copper, nitrate, etc., are not essential.

Oxidation and Reduction.
(Five periods.)

Review (1) oxidation in terms of direct union with oxygen; (2) reduction in terms of the removal of oxygen.

Oxidation as applied to direct union of a metal with any non-metallic element such as sulphur and chlorine.

Experiments to show oxidation such as ferrous to ferric compounds, as for example, ferrous hydroxide to ferric hydroxide, ferrous chloride to ferric chloride.

Experiments to show the reduction of a ferric salt to a ferrous salt, mercuric chloride to mercurous chloride. Brief explanation of oxidation and of reduction in terms of change in composition and of change in valency.

Experiments to show the oxidizing action of such substances as nitric acid, hydrogen peroxide, potassium permanganate. Experiments to show the reducing action of such substances as aluminium, hydrogen sulphide, carbon monoxide (demonstration).

Electrochemical Series.
(Three periods.)

Recall relative activity of metals such as sodium, calcium, magnesium, zinc, iron, copper, silver with oxygen, water and dilute acids.

Experiments to show displacement of metals from solutions of their salts.

A discussion of the relative stability of metallic oxides such as (1) aluminium oxide, (2) copper oxide, (3) mercuric oxide.

A brief discussion of the electrochemical series (activity series).

Metallurgy.
(Ten periods.)

Occurrence of chemically active metals in combined state. Occurrence of less active metals in either combined state or free in nature.

Principle of concentration by flotation and sedimentation.

General methods of extraction:

(a) Roasting—sulphides or carbonates of zinc, lead, nickel.

(b) Reduction—oxides of iron, lead, zinc, chromium.

(c) Electrolysis—aluminium, sodium.

Purification by electrolysis—copper, gold.

Metallurgy of iron; blast furnace. Meaning of such terms as smelting, flux, slag, pig iron. Wrought iron—puddling furnace.

Steel: Bessemer converter, or open-hearth furnace.

Iron alloys such as stainless steel, tool steel, armour plate.

A brief discussion of heat treatment in tempering of steel.

Commercial Acids.
(*Optional.*)
(Three periods.)

Meaning of the term "C.P." (chemically pure) as applied to common acids.

Hydrochloric acid (muriatic acid) C.P. Discuss the concentration of hydrogen chloride in an aqueous solution saturated in respect to it. Specific gravity of hydrochloric acid.

Nitric acid C.P. A discussion of such specifications as specific gravity, percentage of hydrogen nitrate in this solution.

Fuming nitric acid—a brief discussion of preparation and stability.

Sulphuric acid C.P. Specifications—specific gravity, percentage of dihydrogen sulphate in this solution.

Oleum or fuming sulphuric acid—a brief discussion of its preparation and stability.

Colloids.
(Four periods.)

Illustration of the rate of sedimentation and particle size by an experiment such as the following: Shake some sandy loam soil with water in a tall jar and observe the relationship between the time taken for order of deposition and size of particles as indicated by the stratification of the deposit.

A demonstration of the preparation of colloidal dispersions such as starch in water or arsenic trisulphide in water and the presence of the diffused particles shown by a beam of light—Tyndall effect.

Show that the dispersion will pass through a filter paper and still exhibit the Tyndall effect.

Comparison of the properties of solutions and suspensions, and show from the properties of a colloidal dispersion such as arsenious sulphide that it lies in an intermediate position.

Common occurrence of colloids such as protoplasm in plant and animal cells, egg white, jellies, glue, clay, fog, smoke, skim milk and homogenized milk.

Organic Chemistry.
(Eighteen periods.)

NOTE:—The molecular formulae of the compounds marked with an asterisk (*) are the only ones required. Only a brief discussion of the commercial preparations of organic compounds is expected, except where experiments are indicated.

A brief review of carbon and its compounds. Reference to the division of chemistry into Organic and Inorganic Chemistry. Organic compounds when completely oxidized form carbon dioxide and water.

HYDROCARBONS:

Methane*. Occurrence and uses of methane. The methane series (paraffins). A brief discussion of the structural formula of the members of this series to show their relationship. The substitution derivatives of methane—methyl chloride*, chloroform* and carbon tetrachloride*.

Petroleum. A demonstration to show fractional distillation by the separation of methyl alcohol, water and caramel. A discussion of the fractional distillation and refining of petroleum into naphthas, kerosene, lubricating oils and vaseline. The cracking of oils.

Ethylene series. A brief discussion of the ethylene series.

Acetylene series. The preparation, properties and uses of acetylene*. A brief discussion of the acetylene series.

CARBOHYDRATES:

A brief discussion of the composition and properties of carbohydrates—sugars, starch and cellulose, and of their production in plants by photosynthesis.

Sugars. Sucrose*—experiment to show inversion into simple sugars such as glucose*. Lactose*.

Oxidation (burning) of glucose within living cells with liberation of energy (metabolism).

Starch*. Characteristics of starch. Hydrolysis of starch into simple sugars such as glucose. Reference to action of saliva on starch.

Cellulose*. Characteristics of cellulose. Cellulose products —nitrates, rayon, cellophane.

ALCOHOLS:

Relationship of structural formula of alcohols to the hydrocarbons. General properties of alcohols.

Methyl alcohol*. Discussion of preparation by (a) destructive distillation of hard wood, (b) synthetic method from carbon monoxide and hydrogen. Properties and commercial uses.

Ethyl alcohol*. Experiment to show the preparation of ethyl alcohol by the action of yeast on a 10% glucose solution (corn syrup diluted).

Glycerol (as an alcohol).

ORGANIC ACIDS:

A brief discussion of organic acids; fatty acid series. Reference to preparation and uses of acetic acid.

Reference to the acids of other series—lactic acid, oxalic acid, tartaric acid and citric acid.

OILS AND FATS:

Recall the properties and test for fats (Grade X).

A brief discussion of animal and vegetable oils and fats as esters of fatty acids.

Soap and soap making. Hydrogenation of oils (olein). An experiment to show the emulsifying power of soap. The cleansing action of soap. Experiment to show the action of hard water on soap.

PROTEINS:

Complex organic compounds containing nitrogen.

Recall the properties and tests for proteins (Grade X).

Examples: hair, flesh, natural silk, legumes, milk (casein and albumin), gelatin, egg white.

RECOMMENDED TEXT-BOOKS

High School Chemistry. Bruce. Renouf Publishing Co.

Chemistry at Work. McPherson and Henderson. Ginn & Co.

A First Book in Chemistry. Bradbury. D. Appleton.

Senior Chemistry for Canadian High Schools and Colleges. Cornish. Copp, Clark Co., Ltd.

Introductory College Chemistry. Alexander Smith. The Century Co.

Inorganic Chemistry. Bristow.

Dominion High School Chemistry. Bigelow, Morehouse. Macmillan Co.

Elementary Chemistry. Book II, Littler. Clarke, Irwin and Co. Ltd.

PHYSICS, GRADE XIII

While it is not the intention of the Minister to introduce a new course in Grade XIII Physics until September, 1941, the following course is submitted in order that the teachers of this subject may become familiar with the recommendations of the Science Committee and have an opportunity to make comments on what will be recognized as a definite departure from the present course. Suggestions of changes in the new course submitted may be sent to the Deputy Minister.

Introduction

The purposes in view are as follows:

1. To present a course with sufficient balance between experiment and theory to hold the interest of the average pupil.
2. To make a survey, with sound mathematical background, of the general field of physics, so as to meet the needs of the pupil whose academic career ends at this stage.
3. To give to the pupil an introduction to some of the newer applications of physics.
4. To bridge the gap between the secondary school and the university in such a way that there will be as little time lost as possible in adjusting the first-year pupil to university methods.

(a) Mechanics

Motion. (Three periods.)	A review of velocity and Newton's First Law of Motion. Uniform velocity.
(Twelve periods.)	A quantitative study of uniformly accelerated motion with illustrative experiments, e.g. with Galileo board or Fletcher trolley. Graphical representation of uniform motion and of uniformly accelerated motion. Meaning of velocity at a point. Experimental determination of acceleration due to gravity. Problems.
(Fifteen periods.)	Newton's Second Law of Motion. Experimental illustration. Momentum and impulse. Inertia. Distinction between weight and mass. Relation between gravitational and absolute units of force; gram and dyne; pound and poundal. Problems.
(Nine periods.)	Newton's Third Law of Motion. Meaning of stress. Law of Conservation of Momentum. Applications and problems. Centripetal and centrifugal forces. Applications. A discussion of the Law of Universal Gravitation with brief reference to any illustrative experiments.
Energy. (Eighteen periods.)	A review of work, energy, and power, with applications and problems. Definition of units: erg, joule, gram-centimetre, foot-poundal, foot-pound, watt, horse-power, kilowatt-hour, watt-second.

Gravitational potential energy; definition and derivation of formula (mgh).

Kinetic energy; definition and derivation of formula ($\frac{1}{2}mv^2$). Discussion of Joule's determination of mechanical equivalent of heat. Meaning of the efficiency of a machine.

Friction.
(Eight periods.)

Experiments to illustrate static, limiting static, and kinetic friction.

Experimental determination of the coefficients of static and kinetic friction.

Laws of friction (problems not required).

The role of friction in the operation of machines.

Reduction of efficiency of machines by friction.

(b) Electricity

Electrostatics.
(Two periods.)

A review and extension of electrostatics of Grade XII.

An experiment to show that both positive and negative charges are induced on an uncharged insulated conductor when a charged body is brought near it (Canton's experiment).

(Two periods.)

Demonstration and discussion of the charging of an insulated conductor by induction. Explanation in terms of electrons.

(One period.)

An experiment to show that a charge placed on an insulated hollow conductor goes to the outer surface, e.g. Faraday's ice-pail experiment.

A brief discussion of shielding with practical application, e.g. in a radio tube.

(Two periods.)

An experiment to show the escape of a charge from a point, e.g. Franklin's experiment. The lightning rod.

(Three periods.)

Meaning of potential difference.

Review the meaning of work, energy, and power, with emphasis on gravitational potential energy.

A demonstration with a positively charged pith ball (at the end of a short silk thread tied to a glass rod) between two charged insulated plates, one positive, the other negative, to show (1) the existence of a force acting on the pith ball anywhere in the region between the plates, (2) that the pith ball, if free to move, will go from the positive to the negative plate, and (3) that work must be done on the pith ball to move it from the negative to the positive plate.

Explanation of the meaning of potential difference as a difference in potential energy and of the movement of charges, if free to move, whenever a potential difference exists. Reference to the volt as a practical unit of potential difference.

Measure of the magnitude of potential difference by the length of the spark obtained from an electrophorus or induction coil or other apparatus.

Capacity.
(Seven periods.)

An experiment with an electroscope and attached insulated plate (condensing electroscope) to show the variation of capacity with (1) area of plate, (2) distance between the charged plate and a grounded plate, and (3) the nature of the dielectric. Structure and use of condensers of different forms. Derivation of $Q = CV$, where Q is the quantity of electricity, C the capacity, and V the potential. The farad and micro-farad. Simple problems. An experiment with condensing electroscope to show the presence and the nature of the charge on each terminal of a voltaic cell.

Electrical Energy.
(Eight periods.)

Measurement of electric energy and electric power. Proof that the energy gained when Q coulombs move in a wire under a potential difference of V volts is VQ joules, and that the electric power is VI watts, I being the number of amperes and the volt defined as such a potential difference that the work done per coulomb is one joule.

The meaning of kilowatt-hour as a unit of energy. Calculation of the cost of energy in using electrical appliances.

Electrical method of measuring the mechanical equivalent of heat. Simple problems.

Thermionic Emission.
(Three periods.)

An experiment with a diode tube (any radio tube may be used) to show that a current passes through the tube if (1) the filament is hot, and (2) the filament is negative with respect to the opposite electrode.

Simple discussion of the liberation of electrons from a hot metal.

Experiment using A.C., to show the use of a radio tube in allowing current to flow in one direction only.

The meaning of rectifier and rectification.

Photoelectricity.
(Two periods.)

An experiment to show that when light from an arc falls on a clean zinc plate connected to a negatively charged electroscope the electroscope loses its charge. The meaning of photoelectricity; the structure and uses of a simple photoelectric cell and of a phototronic cell.

(c) Energy Transmitted by Waves

Sound.
(Five periods.)

Experiment with a cord under tension to show standing waves. Discussion of this experiment and the principle of superposition by means of graphs representing two trains of waves travelling with equal velocity along the same line but in opposite directions. Nodes and loops. An experiment to show standing sound waves in an air column and to measure the wave-length and the velocity of sound in air. An experiment to determine the frequency of a tuning fork, preferably by some form of vibrograph.

(Four periods.)

Discussion of the meaning of resonance as illustrated by experiments (1) with tuning fork and air column and (2) with tuning forks or resonance bars of the same frequency. Sympathetic vibrations. A mechanical illustration of the principle of resonance.

(Four periods.) Experiments to illustrate the interference of sound waves due to superposition: (1) silent points near a sounding tuning fork; (2) Herschel's divided tube; (3) the production of beats. Discussion of the use of interference in Herschel's divided tube to measure the wave-length of sound.

Light.
(Five periods.) The following simple experiments to show that the transmission of light has the characteristics of a wave disturbance:

(a) An experiment to show the spreading out of light when a single straight incandescent filament is viewed through a narrow aperture, e.g., a narrow crack between two fingers held before the eye.

(b) An experiment to show interference of light when the single filament is viewed through two narrow openings.

(c) An experiment to show interference with light reflected from a thin soap-film.

(Three periods.) An experiment with sodium flame and air wedge between two glass strips to measure the wave-length of sodium yellow light.

An experiment with pins and a glass block to measure the index of refraction from air to glass. Proof that $\sin i/\sin r = v_1/v_2$, where v_1 = velocity in first medium and v_2 in the second.

(Seven periods.) An experiment to show deviation through a prism. Experiments to demonstrate the spectrum of white light and the combination of spectrum colours to form white light. A discussion of the range of wave-lengths in the visible spectrum. An examination, by looking through a diffraction grating, of the flame spectrum of a few common elements such as sodium, calcium, and lithium, and of the vacuum-tube spectra of such gases as neon, nitrogen, and hydrogen (an inexpensive diffraction grating will serve).

A brief discussion of spectrum analysis and the uses of the spectroscope and the spectrograph. A brief discussion of the infra-red, and of the ultra-violet portions of the spectra.

Polarization.
(Two periods.) Experiment with two pieces of polaroid to show the nature of plane polarized light. Discussion of the use of polaroid in overcoming glare due to approaching car headlights.

(Two periods.) Experiment with a piece of polaroid to show polarization by reflection from non-metallic smooth surfaces. Discussion of the use of polaroid in overcoming glare due to reflected light.

Radiant Energy.
(Five periods.) A discussion, with experiments where possible, of means of detecting radiant energy, such as (a) the blackened bulb of a thermometer, (b) Crookes radiometer, (c) a thermocouple, (d) photoelectric or photronic cell, and (e) photographic plate.

Experiments to show (i) the difference in the absorption of radiant energy by a dark and by a polished surface, and

(ii) the difference in the emission of radiant energy by such surfaces. Discussion of (i) the reason for silvering a thermos flask and polishing a calorimeter, and (ii) the reasons for the rise of temperature in a hot-house.

Law of Inverse Squares.
(Five periods.)

Geometrical derivation of the Law of Inverse Squares for any kind of radiation from a small source, when there is no absorption.

Experimental verification by the use of a photometer with two light sources of known candlepower, or by use of a photoelectric cell with a single source of unknown candlepower, or by a hot ball and thermocouple.

Experiment to compare the candle-power of luminous sources by any type of photometer.

Brief reference to foot-candle metre and exposure metre.

X-rays.
(Two periods.)

An experiment with a small X-ray tube and an induction coil to show (1) the discharge of an electroscope by X-rays, and (2) the passage of X-rays through such substances as wood and paper.

Brief reference to the origin of X-rays and to the magnitude of their wave-lengths.

Electric Waves.

Brief reference (illustrated if possible by one or more experiments, such as Lodge's resonance experiment) to oscillatory electric circuits and the generation of electric waves.

A discussion of the range of wave-lengths of electric waves, including radio waves. The meaning of kilocycles per second, and the relation of frequency in kilocycles per second to the wave-length in metres.

(d) Applied Optics

Lenses.
(Two periods.)

Review of the formation of images by a converging lens.

Similar experimental study of the diverging lens.

(Six periods.)

Derivation of lens formula:

$$\frac{1}{\text{object distance}} + \frac{1}{\text{image distance}} = \frac{1}{\text{focal length.}}$$

Simple problems based on this formula.

The linear magnification produced by a lens.

Experimental determination of focal length of a converging lens and of linear magnification by measurement of object and image distances.

Magnifying Power.
(Three periods.)

Review of vision by unaided eye and of power of accommodation. Distance of most distinct vision without undue eye strain. Use of a converging lens as a magnifier. Discussion of most favourable position of image (at infinity) to avoid eye fatigue. Definition of magnifying power as ratio of size of image on the retina when object is viewed through magnifier to its size when viewed directly at optimum distance.

(Three periods.) Experiment with two lenses to illustrate the principle of the astronomical telescope. Diagram of ray paths.

Proof that the magnifying power of the telescope (the ratio of the angle subtended at the eye by the image to the angle subtended by the object when viewed directly) is equal to the ratio of the focal length of the objective to that of the eye-piece.

(One period.) Experiment with two lenses to illustrate the principle of the compound microscope. Diagram of ray paths.